Identifying Critical Manufacturing Technologies

Required for Transforming the Army Industrial Base

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Abstract

With reductions to the Department of Defense (DoD) budget, the Army needs to think strategically about which manufacturing issues have the greatest impact on the health of the industrial base. Typically, these decisions are made based on producing specific critical end items (e.g., ammunition, tactical vehicles, and aircraft) but not on the actual life-cycle costs used to produce these end items (e.g., Implementing qualified manufacturing, and inspection processes, supply chain management, materials availability, etc.).

Due to this decision-making model, very little change has occurred in the industrial base over the last several decades, making it difficult to modernize facilities, produce new designs, and incorporate efficient manufacturing processes.

The value and continued success of the Army Industrial Base depends on the cost-savings potential of transformation initiatives and how effectively they are implemented to support acquisition programs. The threefold intent of this paper is, first, to examine 10 critical manufacturing issues to determine which have the greatest impact on the health of the industrial base. Then this paper, in terms of transition initiatives, will present the *Technology Transition Framework*, developed by the Defense Systems Management College in 2009 for "assessing the readiness of a technology to be adapted from a science and technology (S&T) initiative into an acquisition program." Finally, it is important to identify the most useful knowledge management techniques to retain the transition lessons learned.

Interviews with Army program managers and DoD manufacturing technology engineers will provide perspectives about the current Army industrial base and manufacturing issues. Interviews with industrial base manufacturers will help shed light on successful transition practices.

Chapter 1 – Introduction

Manufacturing accounts for 12% of the U.S. gross domestic product (GDP) or $1.6 trillion of the domestic economy, but this percentage is shrinking each decade (Alliance for American Manufacturing, 2013b). About 40,000 U.S. manufacturing plants closed between 2001 and 2008 (Alliance for American Manufacturing, 2013a). For the DoD, this shrinking manufacturing base is even more acute due to the fact that defense materiel makes up a small, yet critical, portion of the overall total. Put another way, DoD needs do not drive the manufacturing sector. Because of this, Congress has passed laws to implement an Army Organic Industrial Base (AOIB) (which only includes arsenals, depots, and Government-Owned Contractor-Operated [GOCO] facilities) to ensure that there will always be a method to obtain critical materiel and ramp up in times of war (McKitrick, 2005). Nonetheless, DoD needs are much greater than what the AOIB alone can supply, thus the DoD must rely on close partnerships with the commercial sector, called the defense industrial base, to procure equipment and materiel ranging from ammunition, tactical vehicles and aircraft, military radios, uniforms, body armor, food, and packaging.

Although the health of the defense industrial base, which includes—but is not limited to—the AOIB, was not a major concern during the late 1990s and early 2000s, recent reports indicate that the subject is gaining attention again. One very high-profile document was the 2010 Department of Defense Quadrennial Defense Review, which called out the importance of the defense industry:

> In order for the Department of Defense to develop, field, and maintain high-quality equipment, it must rely on a robust and capable defense industry. Indeed, America's industrial capacity and capability made victory in World War II possible, maintained the

> technological edge against the Soviet Union, and today helps ensure that our military personnel in harm's way have the world's best equipment and are supported by modern logistics and information systems; thus our technological advantage must be closely monitored and nurtured. (p. 81)

While no one disputes the importance of the defense industrial base and specifically the Army Industrial Base (AIB), there are conflicting opinions about how it should be transformed to meet future needs, ramp up to surge capacity (needed during a time of war), and generally become more efficient with a well-trained workforce (McLeary, 2013). Several DoD programs are intended to meet these challenges to transition technology into the AIB, such as the Defense Production Act Committee (DPAC), Research Development and Engineering Command (RDECOM), Program Executive Offices (PEO), Office of the Secretary of Defense, DoD/Department of Energy research labs, and university and small businesses programs. However, it is important to examine the current programs and transition mechanisms to determine what works best.

Background

The AIB is broadly defined as the domestic manufacturing processes, infrastructure, logistics, and technology required to produce and sustain Army-centric materiel. Typically, materiel such as tactical aircraft, ammunition, tanks, mortars, body armor, and military radios, are produced only for Army or other defense needs. Since the commercial market for these items may be small, or nonexistent, the Army must identify and maintain a manufacturing base to ensure replenishment of stockpiles and access to spare parts. Within this construct, the Army also needs to identify new technologies to transform the industrial base in support of troop modernization efforts. The Army also has its own AOIB, which includes arsenals (GOCO

facilities, and depots. The focus of this paper is wider than simply the AOIB and includes the entire defense industrial base with a focus on the AIB.

The defense industrial base is such a critical national asset that several agencies and committees have been established to ensure its health. For example, the interagency DPAC includes the heads of 17 federal departments and agencies. The committee advises the President of the United States on the use of the rules and responsibilities established by the Defense Production Act. The DPAC publishes the *Annual Industrial Capabilities Report to Congress* per the Defense Production Act (50 U.S.C. App. § 2061 et seq.) and Executive Order 12919: National Defense Industrial Resources Preparedness.

The U.S. Army has established regulations to help manage its own unique, organic industrial base. Army Regulation 700-90 (AR 700-90) provides the policies and procedures for the Army Industrial Base Program and lays out methods to integrate industrial base planning into the acquisition process, but the enormousness of the Army and its needs make this a difficult task. Thus, the Army utilizes its commercial industrial base, along with its organic industrial base and science and technology (S&T) talent, to transform manufacturing processes that drive efficiencies and ensure there is no disruption in materiel supplies to troops. Specific programs, described in AR 700-09, that are designed to transition manufacturing technology into the Army industrial base, include Master Urgency List; Critical and Strategic Materials; Expansion of Productive Capacity and Supply, Defense Production Act, Title III; Industrial Equipment, Plant Equipment Packages and Army Reserve Plants; Production Base Support; and selected programs related to production engineering (including ManTech, Small Business Innovative Reseach, and RDEC S&T).

In the commercial sector, several programs are used to develop novel manufacturing techniques to transform the industrial base. The more common programs are IR&D, venture capital and bank loans. Independent Research and Development (IR&D or IRAD) is independent research work performed, and paid for, by a government contractor that is outside of the scope of any contracts or grants it may have with the DoD. Venture capital and bank loans are monetary investments used by companies to grow their businesses and develop intellectual property (IP). Each program has its pros and cons, but venture-capital-backed companies alone contribute to 11% of private-sector jobs, and their revenues account for 21% of U.S. GDP, which illustrates the importance of other funding streams in addition to DoD investments (National Venture Capital Association, 2011).

With reductions to the DoD budget, the Army needs to think strategically about which manufacturing technologies are essential to its industrial base to best leverage available sources of funding to transform the AIB and ensure future readiness and sustainment. According to an *Army AT&L Magazine* article written by U.S. Army War College fellow LTC(P) Richard B. Debany (2014), "…the Army must manage risk in terms of balancing affordable industrial capability with the ability to meet any manufacturing demands." Or, perhaps instead of focusing on the critically needed end items (such as ammunition, tactical vehicles, and aircraft) a better accounting should be used of the actual life-cycle costs and requirements used to produce and maintain these end items, and this accounting should include implementation of qualified manufacturing and inspection processes, supply chain management, and materials availability. Using this decision-making model may help shine light on areas in need of transformation such as facilities modernization, design-for-manufacture, workforce training and the incorporation of efficient manufacturing processes.

Many key areas are deemed critical issues, needed to transform the Army industrial base and ensure its continued health. However, for purposes of this study, that list has been narrowed down to 10 general areas:

1. Availability of materials—-avoid proprietary, esoteric, or obsolete materials
2. No domestic supplier/manufacturer
3. Using qualified manufacturing processes (i.e., repeatable processes)
4. Using qualified inspection procedures (i.e., accurate processes)
5. Workforce retention
6. Reducing delivery time
7. Addressing lower-tier supplier issues
8. Contracting difficulties/Reducing barriers to entry into acquisition process
9. Updating drawings and standards
10. Reducing design complexity to improve manufacturability (i.e., reproducible designs, commonality between platforms)

This list is by no means definitive. However, a careful reading of the *Annual Industrial Capabilities Report to Congress* (Under Secretary of Defense for Acquisition, Technology and Logistics [USD(ATL)], 2012) suggests that each of the 10 critical issues listed above is a factor in every defense sector: aircraft, electronics, engineering contract services, cyber technology, materials technology, munitions and missiles, shipbuilding, and space technology.

Each defense sector also has niche manufacturers that produce products that only have military applications. Due to the complexity and criticality of niche manufacturers, the Deputy Assistant Secretary of Defense for Manufacturing and Industrial Base Policy (DASD[MIBP]) has been tasked to implement a sector-by-sector, tier-by-tier assessment that will provide

information “to categorize, identify, and monitor the vast and complex base upon which our soldiers rely, from the shoestrings on their boots to the ships they sail” (USD[ATL], 2012).

Along the same lines, the Program Executive Officer for Ammunition (PEO-Ammo) started to prepare a strategic master plan to ensure the health of the industrial base to produce ammunition for the Army. Now, the Army has established a Single Manager for Conventional Ammunition (SMCA), who collaborates with industry to assess the needs of the industrial base. These needs roughly coincide with the list of 10 critical issues listed above, but also include information such as the minimum sustaining production rates (Seraphin & Palaschak, 2014). Thus, it is important to note that the DoD has recognized the importance and, in some cases, the fragility of the defense industrial base.

A 2004 study by the National Research Council of the National Academies (NRC, 2004, p. 3) recommended that the DoD “should endeavor to create a culture that fosters innovation, rapid development, and the accelerated deployment of material technologies.” In addition to urging improved communications between government users and industry partners, the study recommended that DoD “provide consistent funding during the technology development stage through full maturity” and “update standards and testing procedures to make it easier to introduce new materials and processes.” Another key point of the NRC study was the importance of sharing knowledge and updating materials databases as a means of retaining corporate knowledge in the DoD community. The NRC study focused on finding ways to transition science and technology into improved military materiel solutions—not necessarily to transform the industrial base. Nonetheless, several themes emerge from this paper to define the necessary paths a technology must travel before it is mature enough for transition.

In 2009, the Defense Systems Management College published a *Technology Transition Framework* that took the NRC recommendations a step further. The framework was designed specifically for military projects to assess technology readiness. It consists of five questions a program manager or project engineer should answer "yes" to before inserting a new technology into an acquisition program:

1. Are requirements documents available for supporting transition?
2. Has follow-on funding been provided?
3. Is the military utility assessment (MUA) convincing?
4. Has the project assessed manufacturing and sustainment costs and risks?
5. Has the project examined commercially available technology prior to proprietary technology?

Thus, for a better chance of success in transforming the AIB, it is important not only to address the 10 critical technology issues but to utilize the *Technology Transition Framework*. The goal is not to change the industrial base merely in order to use the latest "gee-whiz" materials or manufacturing processes but to transform the base through innovations that foster competition, maintain or enhance workforce expertise, or reduce delivery times. Overall, "sustaining the capability and capacity to meet the Army's current, anticipated and potential surge requirements is paramount" (Debany, 2014, p. 148). Finally, once a new technology has been successfully transitioned, it is imperative to store the information in a proper repository for future use. Certain DoD groups such as the DASD(MIBP) have databases and perform surveys to reduce duplication of projects and capture lessons learned. Knowledge management can also lead to greater commonality and standardization among acquisition programs.

Problem Statement

In the past year, have any Army projects or programs been negatively impacted by a deficiency in the AIB due to critical technology issues defined in the Annual Industrial Capabilities Report to Congress 2012?

Purpose of This Study

1. Examine which of the 10 technology issues have the greatest impact on the AIB.
2. Introduce the five *Technology Transition Framework* questions to measure the maturity of a new technology and its readiness for use in an acquisition system.
3. Identify the best repositories for knowledge management and lessons learned.

Significance of This Research

With significant budget reductions throughout DoD, the health of the AIB depends on smart investments in transforming effective technologies that address the most critical manufacturing issues. Lessons learned need to be stored and shared in a useful knowledge-management repository.

Overview of the Research Methodology

This research study uses both quantitative and qualitative methods, which include a survey (Appendix A) and in-depth interviews with a variety of people working for RDECOM, the U.S. Army S&T community, PEOs, and Program Management Offices (PM), small businesses and nonprofit organizations committed to understanding and implementing manufacturing technology for the U.S. Army.

The quantitative survey was used to gather demographic information to determine which of the 10 critical issues were the most important to responders based on which population they belonged to. Insight regarding the most successful technology transition mechanisms and use of

knowledge management was gleaned. The qualitative survey was conducted to gather more narrative information on the research questions.

Research Questions

1. (Critical Issues) In the past year, have any of the Army programs you are involved in been impacted by a deficiency in the industrial base? If so, why?

2. (Critical Issues) How important are the following critical manufacturing issues to the Army Industrial Base?

   1. Availability of materials—avoid proprietary, esoteric or obsolete materials
   2. No domestic supplier/manufacturer
   3. Using qualified manufacturing processes (i.e., repeatable processes)
   4. Using qualified inspection procedures (i.e., accurate processes)
   5. Workforce retention
   6. Reducing delivery time
   7. Addressing lower-tier supplier issues
   8. Contracting difficulties/reducing barriers to entry into the acquisition process
   9. Updating drawings and standards
   10. Reducing design complexity to improve manufacturability (i.e.. reproducible designs, commonality between platforms)

3. (Technology Transition) What programs have you used to facilitate the transition and adoption of new manufacturing technologies into the Army Industrial Base?

4. (Technology Transition) Which technology "test beds" have you found to be the most effective in transitioning new manufacturing technologies?

5. (Knowledge Management) How effective are the outlets to raise issues of importance to the Army Industrial Base (journals, conferences, workshops, courses, internet, program reviews, calls for proposals, etc.)?

6. (Knowledge Management) Where do you store drawings, lessons learned, final reports and manufacturing documents after a project is complete (database, server, hard drive, DTIC [Defense Technical Information Center], etc.)?

7. (Technology Transition) Rate the significance of the following factors that led to both a successful and unsuccessful technology transition: documentation, funding, military need, accurate assessment of manufacturing readiness level, communication.

Research Hypothesis

The hypothesis is: "In the past year, were any Army projects or programs negatively impacted by a deficiency in the industrial base due to critical technology issues defined in the 2012 *Annual Industrial Capabilities Report to Congress*?"

Objectives and Outcomes

The objective of this research is to identify which, if any, programs have experienced issues with acquiring materiel. Then, the research aims to identify the most troublesome issues facing the industrial base to make possible a greater S&T focus on those areas.

Limitations of the Study

This is intended to be a pilot study due to the small population. The study asked participants to focus on manufacturing issues in the past year to focus better on current issues and not historical trends. It is hoped that this study will be useful as a planning tool to align resources where they will benefit the Army most in long-term materiel sustainment. The study limitations include data availability and/or access to competition-sensitive information. Three

hundred surveys were submitted and 42 responses were received. Five qualitative interviews were conducted to obtain more in-depth narratives.

Validity of the Research

Possible threats to validity include selection, effects of selection and unique program features. To account for these threats, the survey was emailed anonymously to lists of engineers working for both industry and the U.S. Army. Thus, some survey recipients may not be involved with AIB activities and would not be expected to respond. Three respondents claimed to have experienced a bug in the survey software. In those instances, follow-up interviews were conducted in person to complete the survey.

Reliability of the Responses

The survey was designed to collect information regarding the recipient's involvement with the AIB. If a recipient had no involvement, the survey would stop. Additionally, the survey included information that communicated the intent of this research topic and the option to answer "Other" so respondents were not forced to select an answer with which they felt uncomfortable. Thus, participants had access to information needed to accurately and consistently respond to the appropriate survey questions.

Chapter 2 – Literature Review

This literature review is intended to show the purpose of the AIB and the 10 critical technology issues that have appeared consistently in studies concerning deficiencies in the defense industrial base and that are driving the need for transformation. Also, this report intends to give some visibility to technology transition frameworks and processes that have transformed the industrial base and the importance of having databases and sharing knowledge to avoid costly mistakes and ensure that the U.S. Army does not keep paying for the same studies again and again.

Army Industrial Base Purpose

The purpose of the AIB is defined in Army Regulation 700-90 (AR 700-90), which provides the policies and procedures for the AIB and lays out methods to integrate industrial base planning into the acquisition process. However, the overall purpose of the AIB is broadly defined as the domestic manufacturing processes, infrastructure, logistics, and technology required to produce and sustain Army-centric materiel.

The AIB is especially critical during times of war when the need for Army-centric materiel is urgent and the commercial sector cannot provide it. However, according to Yudken (2010), many questions have been raised about military reliance on foreign sourcing as “a tacit recognition that the United States lacks the commercial manufacturing capacity to supply vital products needed by America’s defense industrial base.” Most Americans acknowledge that most of their electronics for home use often come from China or other foreign sources and the same can be said for the U.S. military.

Thus, there is a critical need to identify areas of the greatest concern to the AIB. For example, instead of propping up obsolete or inefficient production lines, it may be wiser to invest

in newer manufacturing technologies and gradually transform the AIB. Authors Aaron Martin from Northrop Grumman and Ben FitzGerald from the Center for a New American Security (2013) make the case for using novel manufacturing processes, such as additive manufacturing, along with digital technology so that "robots can build robots." This idea builds on that put forth by Chief of Naval Operations (CNO) Admiral Jonathan Greenert who makes the case for "payloads over platforms." The CNO suggests that, rather than build expensive platforms, the industrial base should focus on improving the capability, adaptability and functionality of payloads (e.g., armaments, sensors, communications systems). This would allow the industrial base to use newer manufacturing technologies and inspection methodologies.

Ten Critical Technology Issues

Many studies have been done to identify critical Army-centric end items and to protect the manufacturing base around them. For example, the Army has established the SMCA under DoD Directive 5160.65 and DoD Instruction 5160.68. However, it also is useful to take a broader view of the entire defense industrial base to determine if there are critical technology issues that cross over the various Services and defense sectors.

In the *Annual Industrial Capabilities Report to Congress* (USD[AT&L], 2012), roughly 10 recurring critical issues were found in every defense sector: aircraft, electronics, engineering contract services, cyber technology, materials technology, munitions and missiles, shipbuilding and space technology. The critical issues are availability of materials, no domestic supplier/manufacturer, using qualified manufacturing processes (i.e., repeatable processes), using qualified inspection procedures (i.e., accurate processes), work-force retention, reducing delivery time, lower-tier supplier issues, contracting difficulties/reducing barriers to entry into the

acquisition process, updating drawings and standards, and reducing design complexity to improve manufacturability.

Technology Transition Framework

The 2004 NRC study, presented several suggestions that defined the necessary paths a technology must travel before it is mature enough for transition. One suggestion was to “create a culture for innovation and rapid technology transition” which emphasized teaming and workforce empowerment. Another suggestion was to “make the business case” using prototypes to better demonstrate new technologies and mature these technologies prior to full-scale manufacturing. Finally, placement of technology transition lessons learned in accessible databases and communications throughout the engineering phase were identified as critically essential to transition technology.

In 2009, as part of the PMT 401 course, the Defense Systems Management College published a *Technology Transition Framework* that helped to distill the essential elements needed to successfully transition technology into a defense acquisition program. The *Technology Transition Framework* consists of the five (following items: requirements documents, follow-on funding, a convincing military utility assessment (MUA), manufacturing and sustainment costs and risks, and assessing commercially available technology prior to proprietary technology.

Knowledge Management

Often overlooked in the rush to acquire a new defense capability is the need for knowledge management. The DoD has often paid for multiple studies to solve the same engineering and manufacturing issues. This may, or may not, have been avoided through the proper use of databases and collaboration software that allow for designs and manufacturing processes to be shared. Unfortunately, some of this information may be deemed proprietary by

various commercial manufacturers. However, careful documentation of lessons learned or materials databases could significantly decrease risk on DoD programs.

Ericsson, Prietula, and Cokely (2007, p. 2) maintain that “expertise is not captured by knowledge management systems,” because they are simply “repositories of images, documents and routines.” This is true. However, the contention can be made that experts need access to these images, documents, and routines in order to properly diagnose and troubleshoot manufacturing and engineering problems.

The 2004 NRC study suggests “the Office of Science and Technology Policy should lead a national, multiagency initiative in computational materials engineering to address three broad areas: methods and tools, databases, and dissemination and infrastructure” (NRC, 2004, p.7). The intent here is to share materials properties as a result of manufacturing processes so that engineers can better design and predict failures of defense materiel.

Thus, knowledge management cannot replace expertise, but it can enable experts to access critical information required to support the implementation of new technologies that are needed to transform the AIB.

Chapter 3 – Research Methodology

This chapter describes the research methodology including hypothesis, research process, and data collection used to explore whether Army projects and programs have been negatively impacted by deficiencies in the industrial base due to critical technology issues defined in the *Annual Industrial Capabilities Report to Congress* (USD[AT&L], 2012).

This survey was designed to gather the opinions of Army engineers, their industry counterparts, and acquisition professionals engaged in procuring Army-centric materiel obtained from the AIB. Specifically, opinions regarding the most critical issues facing the AIB, the most useful technology transition methods, as well as current practices regarding knowledge management were sought as a means to determine where precious resources should be spent to transform the AIB and alleviate deficiencies.

Research Hypothesis

For this research project, the *null hypothesis* (H_0) is: In the past year, *no* Army projects or programs have been negatively impacted due to a deficiency in the industrial base. The alternative hypothesis (H_1) is: In the past year, some Army projects or programs have been negatively impacted due to a deficiency in the industrial base.

Research Process

The survey included three sections with a total of 12 qualitative questions plus one free-form text box that allowed participants to put down any additional thoughts and opinions. The questions were designed to solicit comments from the Army S&T community, industrial partners and program managers engaged in designing, developing or acquiring army materiel. The survey was sent to RDECOM-ARDEC engineers engaged in manufacturing engineering, PEO-Ammunition program managers engaged in the acquisition of Army-centric materiel, and

industry partners who provide manufacturing technology and services to RDECOM-ARDEC. The survey questions focused on obtaining the following information:

1. Which of the 10 technology issues have the greatest impact on the AIB?
2. Which of the five *Technology Transition Framework* questions were the most effective in measuring the maturity of a new technology and its readiness for use in an acquisition system?
3. Identify the most useful repositories for knowledge management and lessons learned.

Participants, Population and Sample

There were 42 responses to the survey, which was mailed out to about 300 individuals from: RDECOM-ARDEC, PEO-Ammunition, industry partners and nonprofit organizations with an interest in serving DoD manufacturing needs. Overall, 34 respondents worked for RDECOM-ARDEC, one for PEO-Ammunition, six for industry, and one for a nonprofit organization. Most questions allowed room for additional comments.

Respondents were asked to categorize what "best described their interaction with the army industrial base." Most people surveyed claimed to provide manufacturing services (47.5%), which includes providing drawings, manpower, or research studies. Others claimed to acquire or procure goods for the industrial base (37.5%), while the last group actually provided manufactured goods to the Army (15%). Six respondents claimed to support all three types of interactions with the AIB.

Bias and Errors

The survey sample included only RDECOM-ARDEC engineers and their industry partners. Had the survey included other Army installations, perhaps different issues would have come to light. For example, ARDEC focuses on armaments and is already subject to increased

congressional scrutiny due to the unique nature of ammunition and weapons for the military. However, other organizations that procure more electronics or tactical vehicles may have other concerns that were not reflected in this survey.

All survey respondents provided input voluntarily and most questions were designed to gain subjective opinions. Thus, participants' responses could be biased by their personalities or their latest positive or negative experiences engaging with the AIB. Reduction of bias and error was somewhat controlled through follow-up interviews in which the researcher asked clarifying questions. For example, when "contracting and barriers to entry" started showing up as one of the biggest issues facing the AIB, the researcher dug deeper to verify which contracting mechanisms posed the biggest challenges for both small and large companies that were part of the AIB. In the end, it was discovered that the problem was not contracting *per se* but rather regulatory issues that led to the "high barriers to entry."

Data Collection

The response data were collected on the SurveyMonkey Web-based server and downloaded into Adobe pdf format for processing and graphical figure generation. The survey addressed the three major topics of this research paper. Most data were presented in bar graphs to show visually which answers received the most responses. Two answers were displayed as tables (Table 1 and 2) to better capture the nuances of how people chose to rank the importance of the 10 critical technology issues affecting the AIB and how they store different types of data.

Chapter 4 – Findings

The objective of this research was to determine whether any Army programs have been negatively affected by deficiencies in the industrial base and identify exactly what those deficiencies are. Another objective was to determine which R&D programs and which elements of the *Technology Transition Framework* are the most successful in transitioning new technology to the AIB.

Population & Sample Size

Forty-two respondents answered the survey, which was mailed out to about 300 individuals from RDECOM-ARDEC, PEO-Ammunition, industry partners, and nonprofit organizations with an interest in serving DoD manufacturing needs. Overall, 34 respondents worked for RDECOM-ARDEC, one for PEO-Ammunition, six for industry, and one for a nonprofit organization. Most questions allowed room for additional comments to be made.

Respondents were asked to categorize what “best described their interaction with the army industrial base.” Most people surveyed claimed to provide manufacturing services (47.5%), which includes providing drawings, manpower or research studies. Others claimed to acquire or procure goods for the industrial base (37.5%), while the last group actually provided manufactured goods to the army (15%). Six respondents claimed to support all three types of interactions with the AIB.

Collected Data

The survey asked respondents, “In the past year have any of your programs or projects been negatively impacted due to a deficiency in the industrial base (excluding software)?” Overall, 61.5% of the respondents answered “yes”, with the remaining claiming they had experienced “no problems. See Figure 1.

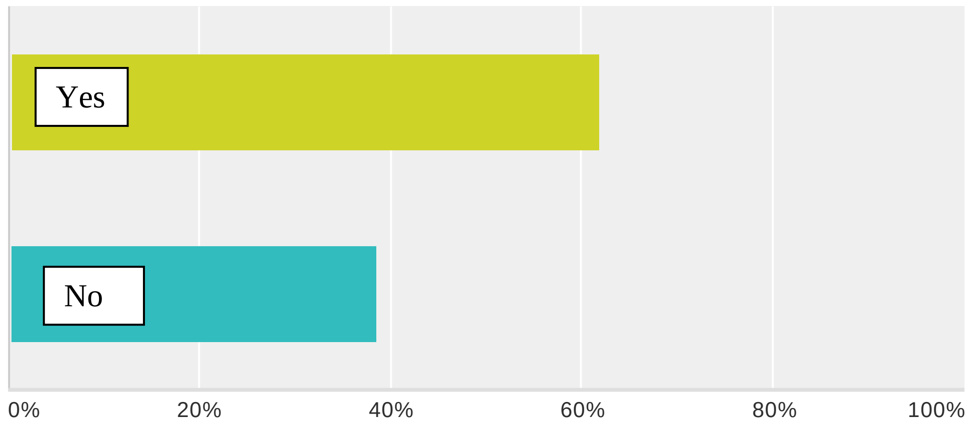

Figure 1 – Percentage of Programs or Projects Negatively Affected by a Deficiency in the Army Industrial Base

For the majority of respondents claiming to be negatively affected by an AIB deficiency, the reason(s) for the problems varied, Figure 2 (multiple responses were permitted). The top four reasons were contracting difficulties/high barriers to entry/fostering competition (77.8%), developing a repeatable manufacturing process (77.8%), no domestic supplier/manufacturer (55.6%) and lack of materials (44.4%). The other six reasons were not determined significant and only garnered one vote apiece.

Interviews with several respondents showed that contracting issues related to encouraging competition were prevalent in both high- and low-dollar value programs. Theoretically, competition can weed out weaker manufacturing technologies so only the best ideas transition to the AIB. However, smaller companies are at a disadvantage in competing because they lack experience with defense contracting or auditing systems. Several, DoD engineers claimed that even using the government credit card for purchases just above the micro-threshold of $3,000 was becoming cumbersome. Because of the competition requirements, DoD employees must get three quotes before purchasing supplies even if a Blanket Purchase Agreement (BPA) or GSA number is in place. The quoting process burdens small companies because it takes time and labor

dollars to produce a quote. Companies have complained to DoD employees that they prefer to produce quotes only when they feel they have a high chance of obtaining the sales. Additionally, several small businesses complained about the high fees charged by credit card companies, a cost that only pays for itself if the small business does many sales with the DoD or other commercial entitiesLarger businesses also expressed concern, in interviews and panel discussions, about the contracting issues related to the DoD efforts to increase competition on high-dollar-value programs. For larger programs, companies are required to submit highly detailed proposals. The proposals are costly to prepare and, although the final dollar amounts are higher when compared to credit card purchases, there also is a higher risk that a company will not get any remuneration for its efforts. Companies also spoke of creeping requirements to develop and demonstrate prototypes during the proposal and bidding process, which add an additional financial burden on the upfront costs. The burden of these costs to compete and bid on DoD proposals has been called a “barrier to entry.”

The third-highest issue noted in Figure 2 was “no domestic supplier” and the fourth-highest issue involved “availability of materials.” One interview with a DoD engineer captured both issues. The engineer said he had been unable to find a domestic supplier of a specific type of steel spring. Both the spring itself and the steel alloy it was made of could not be found domestically. Although most Americans are familiar with the fact that many electronics come from overseas, it may be surprising that some steel alloys and spring configurations are now difficult to obtain in the United States.

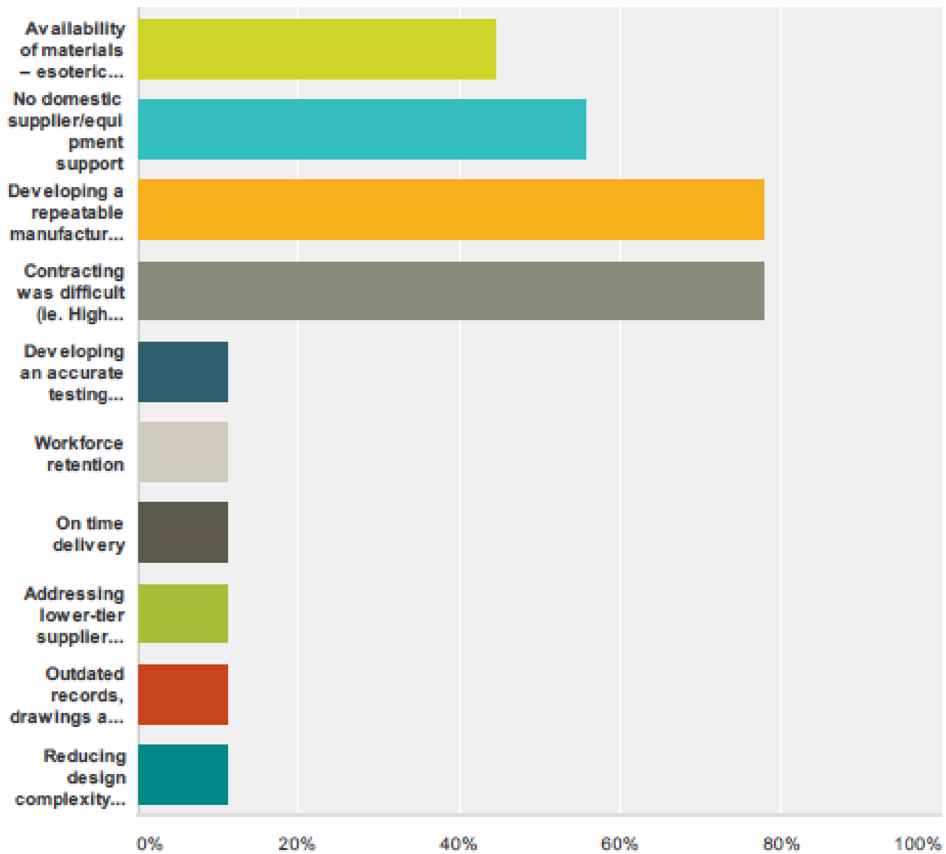

Figure 2 – If You Responded "Yes" to the Prior Question, Please Select the Reason Your Program Was Affected

Regardless of whether the respondents had experienced deficiencies in the industrial base, they were asked, "In the past year, what was your biggest challenge in providing manufacturing goods or services to the U.S. Army?" Thus, even if people did not have a program slippage due to an industrial base deficiency, respondents were given the opportunity to shine light on lingering issues that were a constant source of struggle—see Figure 3. Again, contracting difficulties/high barriers to entry (61.3%) was ranked highest (multiple responses were permitted). Developing repeatable manufacturing processes (38%) and availability of materials were ranked next (38%).

In order to transition new manufacturing technology to the defense industrial base, it is imperative that the technology "repeatedly produce accurate, high-quality products" because the investment in equipment is so high (*Defense Acquisition Guidebook,* 2014) In a panel discussion with one defense manufacturer, the manufacturing engineer explained that the company will only make investments in equipment and facilities that are also "agile." This means that the equipment/facilities can produce both large and small items, or manufacture items made with different materials (e.g., steel, aluminum and titanium).

Climbing somewhat higher in Figure 3, compared to Figure 2, was the "difficulty in reducing design complexity." This pertains to making an item more manufacturable. Engineers who were involved with providing manufacturing services claimed this is their biggest challenge, regardless of whether they came from the DoD, private industry, a non-profit agency, or academia.

Neither "workforce retention" nor "addressing lower-tier suppliers" was listed as a significant challenge in providing manufactured goods to the U.S. Army, although this issue does come up in the *Annual Industrial Capabilities Report to Congress* (USD[AT&L]2012). Interviews and panel discussions with larger companies suggested that maintaining commercially healthy, lower-tier suppliers was a major concern of theirs and that they have increased their vigilance and outreach to the suppliers. Workforce retention is also a concern to larger companies. With the downturn in defense buys, larger defense contractors said they had a difficult time competing for engineering talent against different sectors, like energy. The bigger issue is that engineering talent takes several years to cultivate and, currently, there is not enough manufacturing work to both develop new talent and keep experienced talent practiced. Both DoD

employees and defense contractors agreed that federal budget uncertainties played a large role in hampering long-range plans to help deal with workforce retention and lower-tier supplier issues.

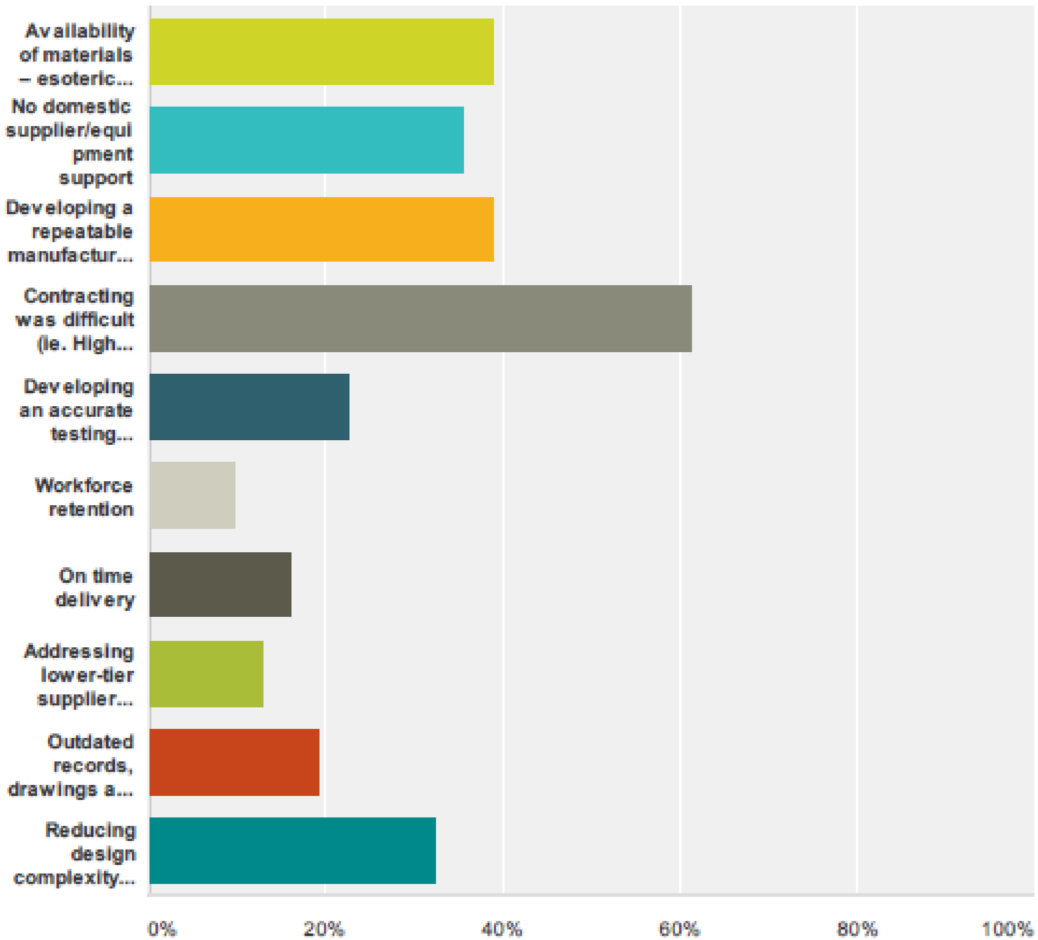

Figure 3 – In the Past Year, What Would You Say Was Your Biggest Challenge in Providing Manufactured Goods or Services to the U.S. Army?

Table 1 – How Important Are the Following Critical Manufacturing Issues to the Army Industrial Base? (Rank the items 1-10, with 1 being the most critical)

	1	2	3	4	5	6	7	8	9	10	Total	Average Ranking
Availability of materials – esoteric or obsolete materials	12% 3	16% 4	32% 8	20% 5	0% 0	4% 1	0% 0	8% 2	4% 1	4% 1	25	7.16
No domestic supplier/equipment support	16% 4	12% 3	8% 2	4% 1	28.00% 7	12% 3	8% 2	0% 0	12% 3	0% 0	25	6.44
Developing a repeatable manufacturing processes	16% 4	12% 3	16% 4	8% 2	4% 1	20% 5	16% 4	4% 1	0% 0	4% 1	25	6.56
Contracting was difficult (ie. High barriers to entry)	16% 4	28.00% 7	4% 1	20% 5	8% 2	4% 1	8% 2	4% 1	0% 0	8% 2	25	7.04
Developing an accurate testing procedure	0% 0	8% 2	8% 2	4% 1	20% 5	16% 4	24% 6	8% 2	12% 3	0% 0	25	5.08
Workforce retention	8% 2	0% 0	8% 2	8% 2	12% 3	4% 1	12% 3	12% 3	16% 4	20% 5	25	4.28
On time delivery	8% 2	8% 2	0% 0	4% 1	16% 4	16% 4	4% 1	20% 5	8% 2	16% 4	25	4.64
Addressing lower-tier supplier issues	4% 1	0% 0	12% 3	12% 3	0% 0	8% 2	12% 3	24% 6	20% 5	8% 2	25	4.28
Updating records, drawings and standards	4% 1	8% 2	4% 1	12% 3	4% 1	8% 2	8% 2	16% 4	20% 5	16% 4	25	4.28
Reducing design complexity to improve manufacturability or maintenance (ie. reproducible designs)	16% 4	8% 2	8% 2	8% 2	8% 2	8% 2	8% 2	4% 1	8% 2	24% 6	25	5.24

Respondents were asked to rank the importance of the 10 critical manufacturing issues to the Army industrial base, Table 1, with 1 being the "most critical". The results of this question generally track with the responses to the earlier questions. Availability of materials, contracting difficulties, developing repeatable manufacturing processes and no domestic supplier again rank as the most critical issues.

However, it is interesting to note that neither "developing an accurate testing procedure" nor "no domestic supplier available" was ever ranked as the *least* critical issue. One DoD engineer stated that some materials, such as organic composites, are difficult to inspect without destroying the part just manufactured. Newer manufacturing technologies, such as *additive manufacturing*, are still in the early stages of standards development. Pauley (2013, p. 35) notes,

"It is an undisputed fact that standards and conformance are critical to the success of products, personnel and services in the marketplace." Thus, for newer technologies to successfully transition and transform the AIB, it will be imperative that new testing and inspection procedures be developed along with conformal standards.

The survey shifted next to asking respondents, "What program mechanisms have you used to facilitate the transition and adoption of new manufacturing technologies into the Army industrial base?" See Figure 4. Respondents were asked to rank the effectiveness of different contracting mechanisms, institutional programs, venture capital and others. A ranking of 5 means the contracting mechanism was "most effective"; a ranking of 1 means that the mechanism was "least effective". A calculated average was obtained based on the percentage of respondents selecting an effectiveness rating.

Over 42% of respondents listed Science and Technology Base Funding as the "Most Effective" at transitioning novel technology, giving it a weighted average of 4.18. Nonetheless, all of the DoD contracting mechanisms were quite close in being effective; DoD R&D contracts had a weighted average of 3.95, Mantech averaged 3.83, and DoD production contracts averaged 3.73.

Over 53% of all respondents claimed to have no experience with either IRAD or venture capital. This bias is most likely due to the fact that most respondents were DoD employees and cannot access funds through either mechanism.

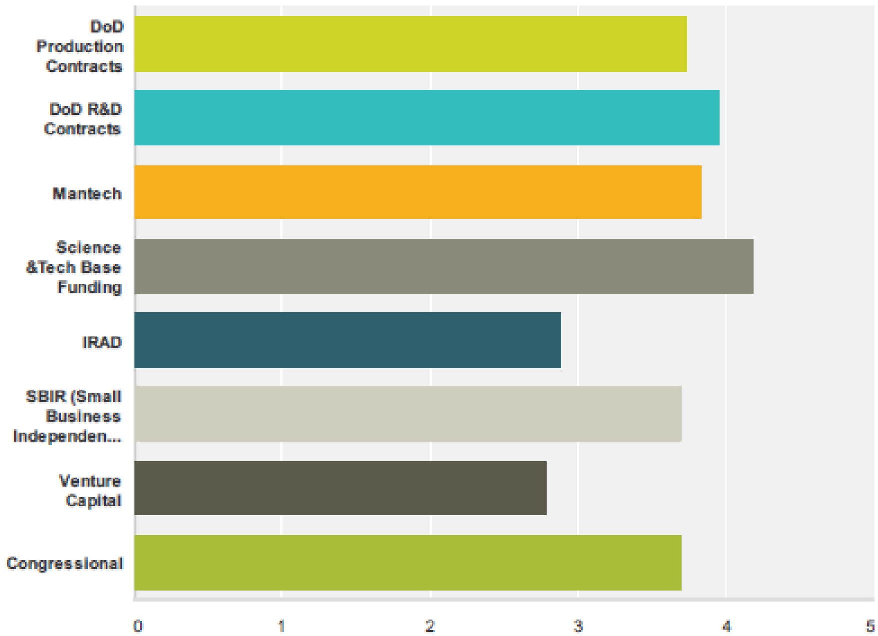

Figure 4 – What Program Mechanisms Have You Used to Facilitate the Transition and Adoption of New Manufacturing Technologies Into the Army Industrial Base (5 = most common mechanism, 1 = least common mechanism)?

The survey next asked, “What technology ‘test beds’ have you found to be the most effective in transitioning new manufacturing technologies?” The results are calculated so that a ranking of 5 was “most effective”, while a ranking of 1 means that the test bed was “least effective.” A calculated average was obtained based on the percentage of respondents selecting an effectiveness rating between 1 through 5. The results, shown in Figure 5, had DoD Prototype Integration Facilities (PIFs) receiving a ranking of 4.15 and industry labs a ranking of 4.05 in terms of being the most effective. Universities/academia ranked at 3.21, somewhat neutral in terms of being effective technology “test beds.” No reasons cited in the comments shed light on these rankings.

One respondent, however, wrote that the best technology test beds were round-robin projects that involved industry, government agencies (including DoD, NASA and the National

Institute of Standards and Technology [NIST]), academia, and nonprofit organizations. In round-robin tests, different entities voluntarily manufacture the same product to the same drawings and specifications. Physical properties and measurements are conducted by third-party test companies. The data generated from these types of tests are then shared by the group and often published for public use. Various organizations—such as the NIST (www.nist.gov), the ASTM International (prior to 2001, the American Society for Testing and Materials; www.astm.org), and the National Center for Manufacturing Sciences (www.ncms.org)—often lead round-robin tests in emerging manufacturing fields such as nanotechnology, additive manufacturing, digital manufacturing, test methodology, and robotics.

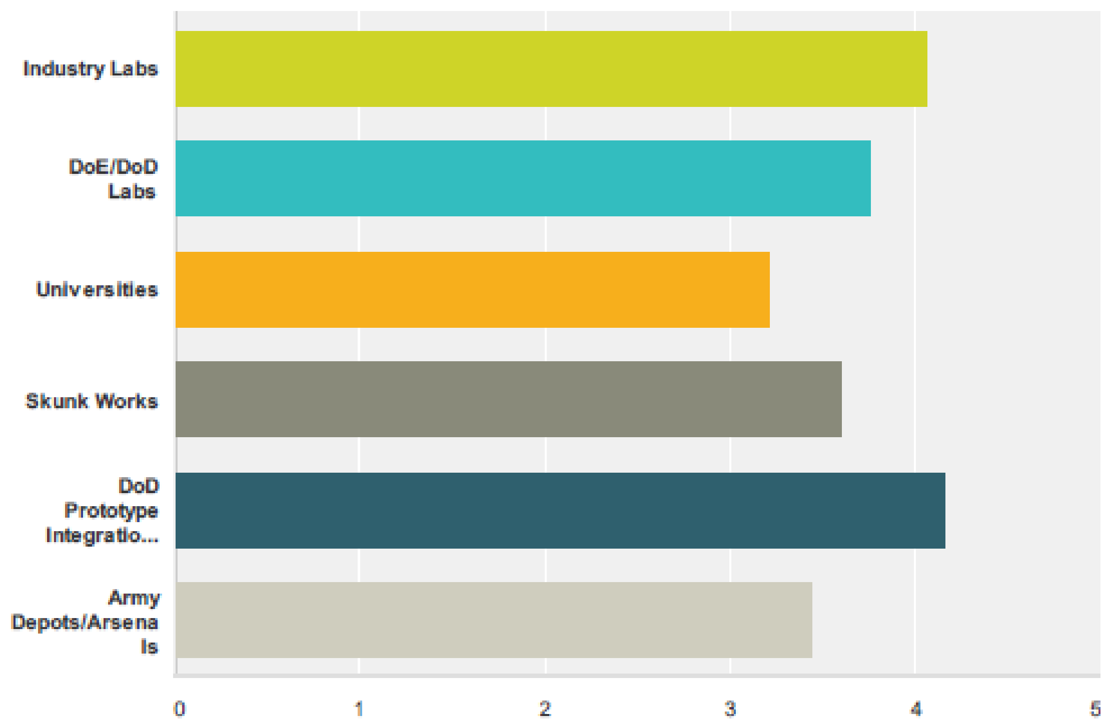

Figure 5 – Which Technology "Test Beds" Have You Found To Be the Most Effective in Transitioning New Manufacturing Technologies (5 = most common mechanism, 1 = least common mechanism)?

Knowledge management was another area of interest in this research project. Two questions were asked to determine what venues were the best for finding information and storing lessons learned regarding the industrial base. The question was, “How effective are the following outlets to raise issues of importance relative to the industrial base?” (Multiple selections were permitted.) A calculated average was obtained based on the percentage of respondents selecting an effectiveness rating between 1 (not effective) through 5 (most effective). Overall, conferences (average ranking, 4.10) and workshops (average ranking, 3.90) were ranked the most effective, while courses were ranked less effective (average of 3.32), Figure 6. One respondent claimed that his/her best information came through informal activities, such as playing sports after work or chatting with coworkers in the cafeteria.

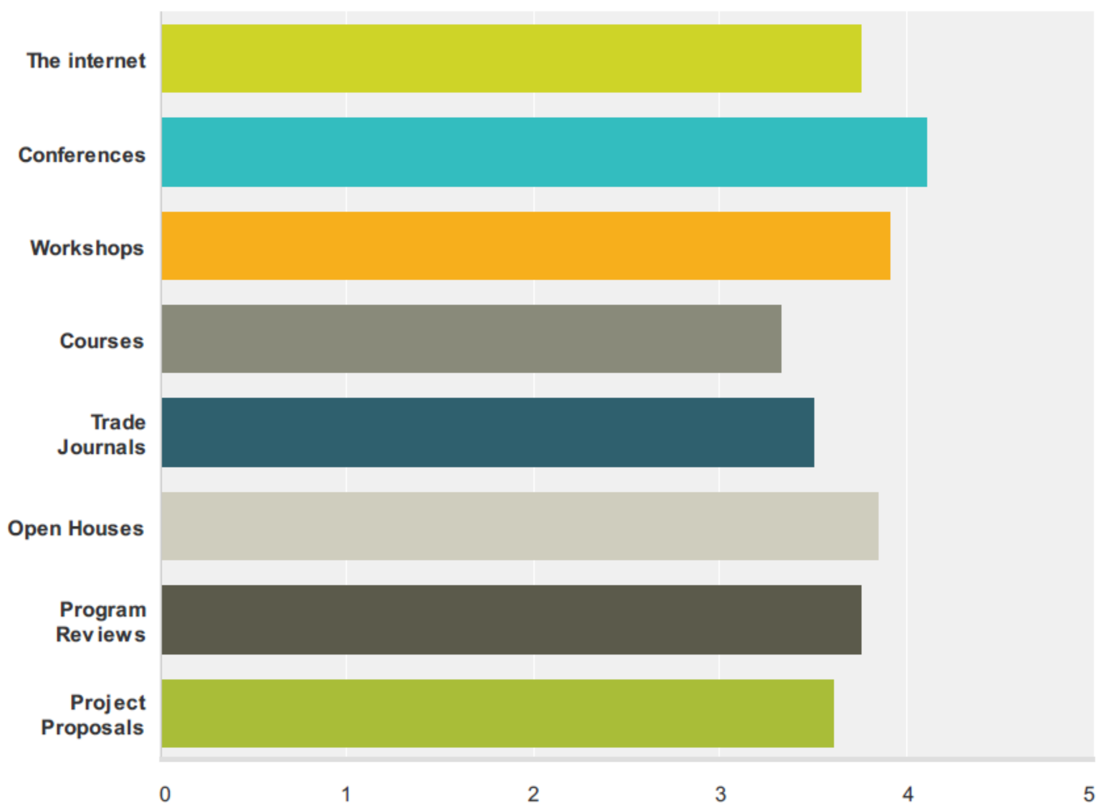

Figure 6 – How Effective Are the Following Outlets to Raise Issues of Importance Relative to the Army Industrial Base (5 = most effective, 1 = least effective)?

The second knowledge management question was, “Where are your knowledge assets, documents, and drawings stored after a new manufacturing technology has transitioned to the army industrial base?” (Multiple selections were permitted.). Drawings and manufacturing documents were most likely to be stored on a local server, hard drive, or shared database. Lessons learned often stayed on local servers or hard drives. Final reports were often stored on a hard drive or a local server. Occasionally, final reports were submitted to DTIC, Table 2.

This question solicited the most comments. Two respondents claimed that establishing good materials databases was essential to performing finite element analyses, which are needed to properly design parts for manufacture. Getting good, reliable data to populate a materials database is often difficult because it is expensive and time-consuming. Another respondent claimed to store most of his/her information in an email folder, which is another form of using a local server to store data. A final respondent claimed that knowledge management was “the biggest problem” facing newer manufacturing technologies.

At best, respondents claimed to have access to a shared server, behind a firewall, where they could freely provide information to other engineers who have the proper clearance. At worst, data developed at a great expense is stored on a hard drive in one engineer’s computer. Knowledge management seems to be dealt with in an *ad hoc* manner based on the type of information stored and shared.

Table 2 – Where Are Your Knowledge Assets, Documents and Drawings Stored After a New Manufacturing Technology Has Transitioned to the Army Industrial Base?

	Defense Technical Information Center (DTIC)	Journal	Local Server	Hard drive	Database	Website	Total Respondents
Drawings	**5%** 1	**0%** 0	**60%** 12	**50%** 10	**55.00%** 11	**5%** 1	35
Manufacturing Documents	**10%** 2	**5%** 1	**65%** 13	**60%** 12	**55.00%** 11	**5%** 1	40
Lessons Learned	**25%** 5	**15%** 3	**55.00%** 11	**55.00%** 11	**25%** 5	**20%** 4	39
Final Reports	**45%** 9	**20%** 4	**50%** 10	**60%** 12	**35%** 7	**15%** 3	45

The last area of interest was to identify which 5 factors in the *Technology Transition Framework* actually had the greatest impact on transitioning new manufacturing technology to the industrial base: documentation, funding, military utility assessment, manufacturing readiness levels (MRLs), communication during technology development. First, respondents were asked to think about a *successful* technology transition and rank the effectiveness of the 5 factors—see Figure 7. In this question, 3 was the value given to the "most significant" factors and 1 was the value given to the "least significant" factors. An average ranking was calculated based on how many respondents selected the factor as being significant or not.

In *successful* programs, follow-on funding had been secured (ranking, 2.95) and there was substantial documentation to support transition (ranking, 2.74)—see Figure 7. For *unsuccessful* programs, 95% of respondents claimed that lack of follow-on funding (ranking, 2.95) was the most significant reason that technology transition did not occur—see Figure 8.

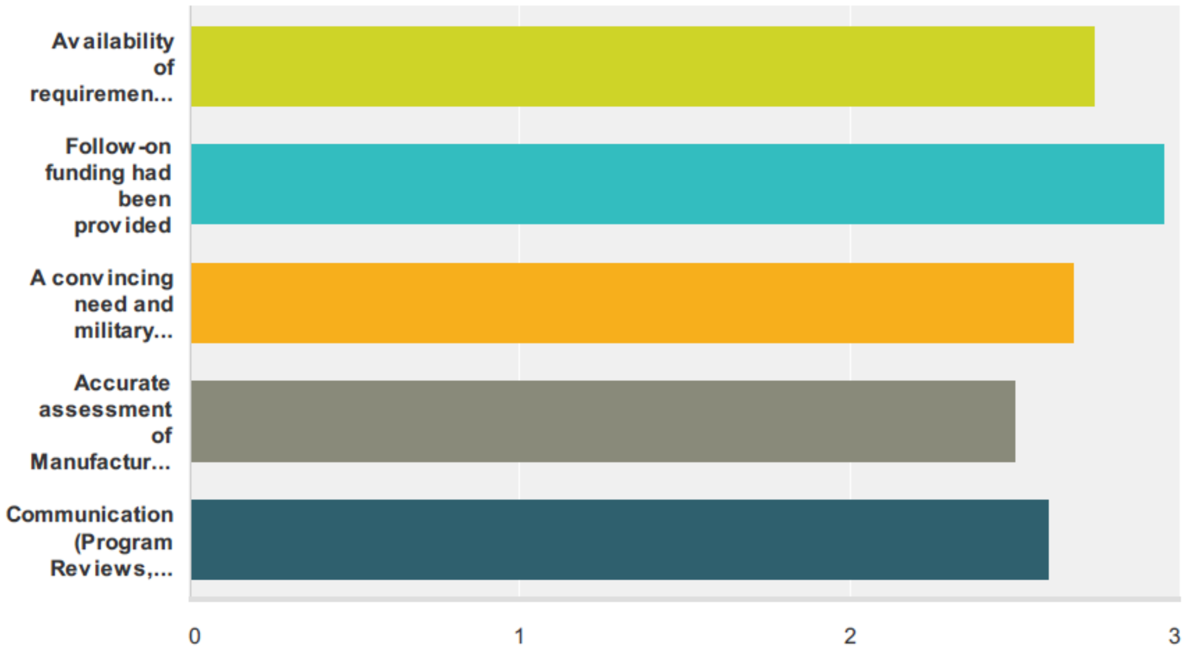

Figure 7 – Rate the Significant Factors That Led to a Successful Transition of Critical Manufacturing Technology Into the Army Industrial Base (3 = most significant)

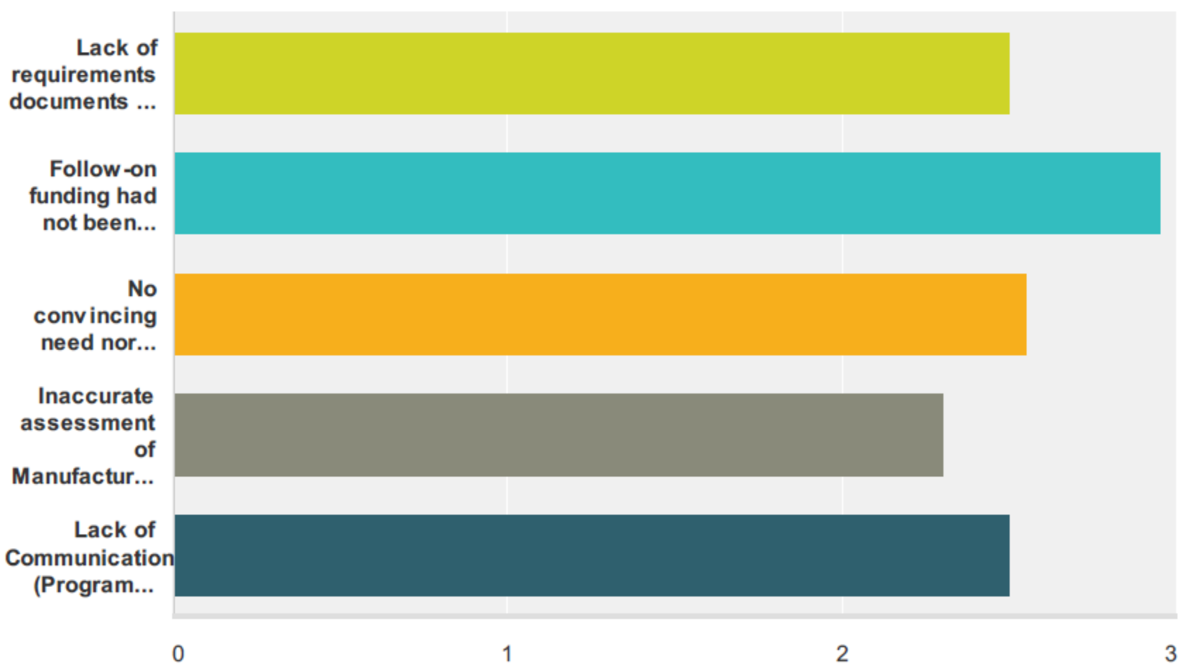

Figure 8 – Rate the Significant Factors That Prevented the Transition of Critical Manufacturing Technology Into the Army Industrial Base (3 = most significant)

Chapter 5 – Conclusions and Recommendations

The focus of this research project was to survey the entire industrial base that serves the U.S. Army, *not just* the AOIB, to determine what deficiencies exist so it will be easier to identify which critical manufacturing technologies are required to transform the industrial base. Survey questions were divided into three categories: Critical Technology Issues, the *Technology Transition Framework*, and Knowledge Management.

Over 60% of the survey respondents stated that their programs or projects had been *negatively* affected by a deficiency in the AIB. Thus, holistically, the Army is wise to pay attention to the problems involved with the industrial base. With scarce resources, however, the Army should focus on the most critical issues listed below.

Critical Technology Issues

Based on a close reading of the *Annual Industrial Capabilities Report to Congress* (USD[AT&L], 2012), 10 critical technology issues were cited that affect all sectors of the defense industrial base: availability of materials, no domestic supplier/manufacturer, using qualified manufacturing processes (i.e., repeatable processes), using qualified inspection procedures (i.e., accurate processes), workforce retention, reducing delivery time, lower-tier supplier issues, contracting issues/reducing barriers to entry, updating drawings and standards, and reducing design complexity to improve manufacturability.

Survey results showed that contracting was so difficult that it represented a “barrier to entry” for smaller firms with novel technology (Erwin, 2004). Payment software, such as Wide Area Workflow, has helped simplify payment procedures; nevertheless, many small firms claim that the contracting process is “bewildering” and express concern about being in violation of regulations such as International Traffic in Arms Regulationsor the Buy America Act. For small

firms, becoming aware of Requests for Proposals, Small Business Innovative Research opportunities, or Broad Agency Announcements is hit-or-miss. Both large and small companies claim that preparing proposals requires a significant investment in time and money, so some prefer to be “unresponsive” to requests for information, proposals and quotes.

The second most critical technology area is developing “repeatable manufacturing processes”. In order to transition newer, more efficient manufacturing processes into the industrial base, it is imperative that industry partners communicate and work closely with DoD engineers and scientists to document that the process is repeatable. This involves what one survey respondent called “ the frustration of demonstrating all the ‘–ilities’: manufacturability, producibility, and sustainability.”. Simply put, if an engineer produces a drawing and a machinist can’t produce it because of blind undercuts or exceptionally tight tolerances, it is not “manufacturable.” If a company produces a dozen widgets, but is unable to make any more that meet specifications, the widget is not “producible.” Finally, if the materials needed to produce the widgets on a large scale are in short supply, the manufacturing process is “unsustainable.” Thus, this critical technology area includes many stakeholders and technologists working together, which is challenging.

Technology Transition

Once a technology has been successfully demonstrated in a laboratory setting or using a small-scale, batch process, it is important to transition it into an industrial setting and scale up the rate of manufacturing. To do this, it is important to have an intermediate step called a technology test bed. Asked to rank the effectiveness of various test beds, most respondents ranked industrial test beds highest, with the DoD PIF second. Close coordination between industry partners and

DoD engineers was cited as being critical to a successful tech transition regardless of which test bed is chosen for technology demonstration.

Respondents were also asked to rank the effectiveness of various programs and contracting vehicles used to support technology transition. Science and Technology Base funding followed by DoD R&D contracts were cited as the most effective. It is possible that the ability to tailor requirements and documentation led to the greatest innovation. Venture Capital and IRAD funding were ranked much lower than DoD sources of funding. This may be due to a bias resulting from most of the respondents being DoD engineers. DoD employees do not have access to venture capital or IRAD and so, would be unable to use these funding sources effectively.

The importance of the five factors laid out in the *Technology Transition Framework* was analyzed: documentation, funding, military utility assessment, manufacturing readiness levels (MRLs), and communication during technology development. This was done by asking respondents to reflect on programs that *successfully* transitioned technology versus programs that did not succeed in doing so.

Regardless of whether or not a technology was transitioned into the industrial base, the presence (or lack of) follow-on funding was listed as the most important requirement. Providing funding is the most “obvious display of support” for a new technology, according to one respondent. Funding allows for contracting, which then enables close communication between all stakeholders. This then allows project members to pull together the documentation that supports the tech transition by demonstrating military utility assessments and manufacturing readiness levels. So, in the final analysis, all five factors are required for successful technology transitions—but it all begins with lining up the required funding. Thus, sustained budget uncertainty will negatively affect technology transition.

Knowledge Management

At the start of any program, it is frustrating to hear that parts of the R&D have been done before but that no one can find any of the prior documentation. Knowledge management, even simply storing raw data, can be very useful in avoiding duplication of work and thereby helpsg to conserve resources. Obtaining information can be challenging too, as some information may be proprietary.

When asked which were the most effective outlets for raising issues of importance relative to the industrial base, respondents stated that conferences were the most effective and college courses the least effective. Conference attendance helped respondents to get the timeliest information in their areas of expertise. College courses were seen as being somewhat stale for the faster-moving technologies, yet were important at giving the respondents a good understanding of fundamentals. One respondent claimed that informal settings (eating lunch with colleagues and playing sports after work) were the sources of the best information.

Open houses and technical workshops were also rated as effective information outlets. Traditionally, these sometimes have a narrow focus—typically showcasing specific equipment manufacturers, universities, or emerging technologies.

After a technology was successfully transitioned, respondents were asked where they stored all of their data. Drawings and manufacturing documents (process parameters) were most often put on a local, shared server. Lessons learned were mostly stored on hard drives, but were sometimes put on a local, shared server. Final reports were usually only stored on hard drives, but were occasionally submitted to DTIC.

Journal articles (and refereed papers) were the least likely places for engineers to share or store manufacturing data. It is not clear why this is so, but several factors may be at work. Based

on the researcher's own personal observations and work experiences, manufacturing engineers are not rewarded for publishing papers but for making products. Another issue is that some facets of a manufacturing process may be proprietary and the risk of revealing trade secrets in the open literature is too high

Recommendations for Future Research

This study was largely limited to RDECOM-ARDEC engineers and their private industry counterparts. Another quantitative survey could be conducted across different Army organizations involved in either acquiring materiel or providing engineering support, such as the Office of the Assistant Secretary of the Army for Acquisition, Logistics & Technology or Army Materiel Command, to see whether contracting issues and "developing repeatable manufacturing processes" are problems across all of the different Army sectors (missiles, vehicles, electronics, aviation, etc.). This information could go far in helping the Army to budget manufacturing projects effectively and make targeted improvements to its industrial base.

The response rate for this survey was just above 10%, which makes it a useful pilot study. Since the survey had been broken into three topics, follow-through and a refined focus on any three of the topics would be worthy of more research. For example, a better understanding of the most effective knowledge management systems can help the Army to best collect and store the precious information it has already paid for.

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Glossary of Acronyms and Terms

AIB.................Army Industrial Base

AOIB..............Army Organic Industrial Base

DASD(MIBP) Deputy Assistant Secretary of Defense for Manufacturing and Industrial Base Policy

DPAC.............Defense Production Act Committee

DoD................Department of Defense

GDP................Gross Domestic Product

GOCO ....Government-Owned Contractor-Operated

H_0 ....Null Hypothesis

H_1 ....Alternate Hypothesis

IRAD..............Independent Research and Development

MRL...............Manufacturing Readiness Level

PIF..................Prototype Integration Facility

RDECOM ......Research Development and Engineering Command (U.S. Army)

S&T................Science and Technology

Appendix A – Survey

Manufacturing Issues Critical to Transforming

Introduction

The army industrial base is broadly defined as the domestic manufacturing processes, infrastructure, logistics and technology required to produce and sustain army-centric materiel. Within this construct, the army needs to identify which issues need to be addressed in order to transform the industrial base in support of troop modernization efforts.

This survey is designed to identify which critical manufacturing issues and transition mechanisms are most suitable for transforming the army industrial base and supporting over-arching, strategic goals.

1. What organization do you work for or represent?

	Industry Partner	US Army	Other Government Agenvy
Select one			

Other (please specify)

***2. Which best describes your interaction with the army industrial base?**

- ◯ I have provided a manufactured good(s) to the US Army
- ◯ I have provided manufacturing services (including R&D, manpower, drawings)
- ◯ I have procured goods or services for the US Army?

Other (please specify)

Industrial Base and Manufacturing Challenges

***3. In the past year, have any of your programs or projects been negatively impacted due to a deficiency in the industrial base? Do not include software issues.**

◯ Yes ◯ No

Manufacturing Issues Critical to Transforming

4. If you responded "Yes" to Question 3, please select the reason your program was affected. (Select all that apply)

- ☐ Availability of materials – esoteric or obsolete materials
- ☐ No domestic supplier/equipment support
- ☐ Developing a repeatable manufacturing processes
- ☐ Contracting was difficult (ie. High barriers to entry)
- ☐ Developing an accurate testing procedure
- ☐ Workforce retention
- ☐ On time delivery
- ☐ Addressing lower-tier supplier issues
- ☐ Outdated records, drawings and standards
- ☐ Reducing design complexity to improve manufacturability or maintenance (ie. reproducible designs)

Other (please specify)

5. In the past year, what would you say was your biggest challenge in providing manufactured goods or services to the US Army? (Select all that apply)

- ☐ Availability of materials – esoteric or obsolete materials
- ☐ No domestic supplier/equipment support
- ☐ Developing a repeatable manufacturing processes
- ☐ Contracting was difficult (ie. High barriers to entry)
- ☐ Developing an accurate testing procedure
- ☐ Workforce retention
- ☐ On time delivery
- ☐ Addressing lower-tier supplier issues
- ☐ Outdated records, drawings and standards
- ☐ Reducing design complexity to improve manufacturability or maintenance (ie. reproducible designs)

Other (please specify)

Critical Manufacturing Issues

This series of questions deals with critical manufacturing issues of general interest to the army industrial base. Please answer these questions based on your opinions and experiences in dealing with manufacturing issues.

Manufacturing Issues Critical to Transforming

***6. How important are the following critical manufacturing issues to the army industrial base? Rank the items 1 - 10, with 1 being the most critical.**

- [ ] Availability of materials – esoteric or obsolete materials
- [ ] No domestic supplier/equipment support
- [ ] Developing a repeatable manufacturing processes
- [ ] Contracting was difficult (ie. High barriers to entry)
- [ ] Developing an accurate testing procedure
- [ ] Workforce retention
- [ ] On time delivery
- [ ] Addressing lower-tier supplier issues
- [ ] Updating records, drawings and standards
- [ ] Reducing design complexity to improve manufacturability or maintenance (ie. reproducible designs)

Technology Transition Mechanisms

These questions identify the various technology transition mechanisms. Please answer these questions based on the different programs you have used and how effective they have been.

7. What program mechanisms have you used to facilitate the transition and adoption of new manufacturing technologies into the army industrial base?

	Least Effective	Less Effective	Neutral	Effective	Most Effective	N/A
DoD Production Contracts	◯	◯	◯	◯	◯	◯
DoD R&D Contracts	◯	◯	◯	◯	◯	◯
Mantech	◯	◯	◯	◯	◯	◯
Science &Tech Base Funding	◯	◯	◯	◯	◯	◯
IRAD	◯	◯	◯	◯	◯	◯
SBIR (Small Business Independent Research)	◯	◯	◯	◯	◯	◯
Venture Capital	◯	◯	◯	◯	◯	◯
Congressional	◯	◯	◯	◯	◯	◯

Other (please specify)

8. Which technology "test beds" have you found to be the most effective in transitioning new manufacturing technologies?

	Least Effective	Less Effective	Neutral	More Effective	Most Effective	N/A
Industry Labs	◯	◯	◯	◯	◯	◯
DoE/DoD Labs	◯	◯	◯	◯	◯	◯
Universities	◯	◯	◯	◯	◯	◯
Skunk Works	◯	◯	◯	◯	◯	◯
DoD Prototype Integration Facilities	◯	◯	◯	◯	◯	◯
Army Depots/Arsenals	◯	◯	◯	◯	◯	◯

Other (please specify)

Knowledge Management of Critical Manufacturing Technologies

***9. How effective are the following outlets to raise issues of importance relative to the army industrial base?**

	Least Effective	Ineffective	Neutral	Effective	Most Effective	N/A
The internet	◯	◯	◯	◯	◯	◯
Conferences	◯	◯	◯	◯	◯	◯
Workshops	◯	◯	◯	◯	◯	◯
Courses	◯	◯	◯	◯	◯	◯
Trade Journals	◯	◯	◯	◯	◯	◯
Open Houses	◯	◯	◯	◯	◯	◯
Program Reviews	◯	◯	◯	◯	◯	◯
Project Proposals	◯	◯	◯	◯	◯	◯

Other (please specify)

***10. Where are your knowledge assets, documents and drawings stored after a new manufacturing technology has transitioned to the army industrial base? (Check all that apply)**

	Defense Technical Information Center (DTIC)	Journal	Local Server	Hard drive	Database	Website
Drawings	☐	☐	☐	☐	☐	☐
Manufacturing Documents	☐	☐	☐	☐	☐	☐
Lessons Learned	☐	☐	☐	☐	☐	☐
Final Reports	☐	☐	☐	☐	☐	☐

Other (please specify)

Assessing Technology Readiness

The next 2 questions deal with assessing technology readiness before it can be implemented into an acquisition program and, by extension, produced by the industrial base.

Reflect on one (1) program that had transitioned successfully to the industrial base versus another that did not transition. Rank the significance of five (5) different factors that may have affected the success or failure.

*11. Rate the significant factors that led to a successful transition of critical manufacturing technology into the army industrial base.

	Not Significant	Neutral	Significant	N/A
Availability of requirements documents for supporting transition (ex.data rights, drawings)	◯	◯	◯	◯
Follow-on funding had been provided	◯	◯	◯	◯
A convincing need and military utility assessment	◯	◯	◯	◯
Accurate assessment of Manufacturing Readiness Levels	◯	◯	◯	◯
Communication (Program Reviews, Update Schedule)	◯	◯	◯	◯

Additional Comments

***12. Rate the significant factors that prevented the transition of critical manufacturing technology into the army industrial base.**

	Not Significant	Neutral	Significant
Lack of requirements documents for supporting transition (ex. data rights, drawings)	○	○	○
Follow-on funding had not been provided	○	○	○
No convincing need nor military utility assessment	○	○	○
Inaccurate assessment of Manufacturing Readiness Levels	○	○	○
Lack of Communication (Program Reviews, Update Schedule)	○	○	○

Additional Comments

13. Please share any additional experiences, positive or negative, that you may have with transitioning technology into the army industrial base. Thank you for your assistance.